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14. ABSTRACT

A system intended for designing and testing High-Speed Electro-Optic interconnection devides and systems was constructed by using a Hewlett Packard 8510C network analyzer system, which is purchased with the equipment grant, and uses a Wiltron 3680V series Universal Test Fixture. This system can test both coaxial devices and non-coaxial devices, whcih have coplanar waveguide structures or micro strip structures, with frequenceis up to 50 GHz. This system has been used in traveling wave electrode design and its optimizing process for high-speed polymer based EO modulator also.

15. SUBJECT TERMS: Travel- wave electrode; high-speed EO modulator; network analyzer

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Abstract

This paper reports our experience in our laboratory with using, and equipping with accessories, the Hewlett Packard 8510C network analyzer system, the system purchased with the equipment grant.

This network analyzer system is made up of these parts:

(1) HP 83651B Synthesized Sweeper
(2) HP 8517B S-Parameter Test Set
(3) HP 8510C Network Analyzer
(4) HP 85056A 2.4mm Calibration/Verification Kit
(5) HP 85052B 3.5mm Calibration/Verification Kit

The network analyzer system which was purchased with the grant enabled us to develop techniques of traveling-wave electrode design, and of device-testing for the EO polymer modulator by measuring the characteristics of the electrode such as impedance, electrical effective dielectric constant and attenuation constant, and by serving as a continuously-frequency-tunable modulation signal source with different frequency-sweep types. These results are mandatory for modulator design, and for the optimizing process, and have been used to improve our design. The network analyzer will also in the future be applied to a modulator packaging process by evaluating the influence of connectors and a stand system that will be added to the modulator in the package process. This information will help us to optimize the stand system. All of these results and benefits would have been more difficult and less reliable, without the network analyzer system.

In order to make the network analyzer system feasible for measuring electrodes that have non-coaxial structure, we have equipped it with certain essential accessories. With their addition, the network analyzer system can measure not only coaxial devices but also non-axial devices with coplanar waveguide (CPW) and micro-strip structures up to 50GHz. The accessories are listed below:

(1) One Wiltron 3680V Universal Test Fixture (UTF)
(2) Two Wiltron 36801 Right-Angle Launchers
(3) Two Wiltron 36803 Bias Probes
(4) One Wiltron 36802 MMIC Attachment
(5) One Wiltron 3680B-15M calibration/verification Kit
(6) One Wiltron 3680-25C calibration/verification Kit

1. Introduction

A vector network analyzer system such as the HP8510C can measure the magnitude and phase characteristics of a microwave network[1].

High-speed EO material-based (including EO polymer and EO inorganic substances) modulators are composed of optical channels and electrical channels (traveling wave electrodes) through which light and microwaves respectively travel in the same direction[2,3,4,5].The optical and electrical channels are near enough to each other so that there are interactions between them. By taking advantage of this interaction, the applied electrical signal (microwave) can modulate the light as they travel together. The electrical channel, whose characteristics are critical to the performance of the modulator, is actually a two-port microwave network. The network analyzer can measure the characteristic parameters of the electrodes such as impedance, attenuation constant, and effective electrical dielectric constant. The results of these measurements can inform and improve the electrode design and provide information to optimize it. Meanwhile, the network analyzer can also be used in device testing by serving as a continuously-frequency-tunable modulation signal source, and in device packaging by being used to evaluate the influence on modulator performance of the connectors and stand system which will be added to the modulator in the package process.

Our research into modulators is focused on the EO polymer-based modulator, and the network analyzer system purchased through the grant plays an important role in our research in this field in electrode design and device testing. It is to make the network analyzer system feasible for this task, that we have added some accessories.

This report describes the use and equipping with accessories of the network analyzer system.

Section 2 provides a brief introduction to our research into the EO polymer-based modulator. The important role played by the network analyzer system is described in section 3. Section 4 introduces the equipping of the system with accessories. The last section describes our measurement setup and some measurement results.

2. Introduction to our research on the EO polymer-based high-speed modulator[5]

There are two primary types of structure for EO material based modulators: Mach-Zehnder structure and directional coupler structure. Our research is focused on the directional coupler structure in which the separation between the two optical channels is small enough to ensure coupling between them.

The goal of our research project is to design and fabricate an EO polymer based modulator with a directional coupler structure. The basic structure of the modulator is shown in Fig. 1. The core portion of the modulator is an optical channel layer made from EO polymer sandwiched inside two cladding layers. There are two layers of electrodes. The bottom electrode is necessary for polymer polling and the top-layer electrodes are used to apply modulation signals. The typical separation between the two optical channels is in the 3-6 μm range and the separation between optical and electrical channels is on the same order. Supposing both the optical and electrical signals travel along z direction (from left to right in Fig. 1(a)), the interaction equation between the two optical channels can be approximated as[6]:

$$\begin{aligned}
&\frac{dR(z)}{dz} - i\delta_0 e^{-dz}(1-\alpha z)\,R(z) = -ikS(z) \\
&\frac{dS(z)}{dz} + i\delta_0 e^{-dz}(1-\alpha z)\,R(z) = -ikR(z)
\end{aligned} \qquad (1)$$

where $R(z)$ and $S(z)$ are the amplitude of the light in the two channels respectively, $\delta(V)$ a variable proportional to the microwave amplitude, α the attenuation constant of the microwave channel, and k a constant that is determined both by the structure of the optical channel, and by the magnitude of the separation of the channels. The electrical signal modulates the light by changing $\delta(V)$.

The above equations show that the attenuation constant can immediately affect output light and its influence cannot be illuminated by changing applied modulation voltages alone. Therefore, it is advantageous to know the attenuation constant or at least a range of it in optical channel design process so that the output light intensity can be calculated using equation (1).

The working principle of the modulator presents the following requirements for electrode design:

(1) Electrode characteristic impedance should be near $50\,\Omega$ ($Z \approx 50\,\Omega$) in order to reduce SWR (the standing wave ratio) and electrical driver power.

(2) Microwave and optical channels should have a velocity match ($\varepsilon_{e,eff} \approx n_{o,eff}^2$). In the above formula, $\varepsilon_{e,eff}$ is the effective electrical dielectric constant of the electrical channel, and $n_{o,eff}$ the effective optical refraction index of the optical channel.

(3) Microwave loss should be kept low (that is, a small attenuation constant, α) to reduce the drive power.

These requirements and the above analysis show the importance of impedance, effective electrical dielectric constant and attenuation constant in modulator design. All of these can be calculated based on the measurement results of the network analyzer.

3. Important role of network analyzer in modulator design and testing

Fig. 2 shows the modulator design process. The steps in which the network analyzer is used are **bold**.

(1) In electrode design[5,7]

Fig. 2 shows that the electrodes are first designed using numerical simulation. Then they are fabricated and measured using the network analyzer. If the results are not satisfying, the design is modified and the former process is repeated. Measuring $\varepsilon_{e,eff}$, Z and α serves as an indispensable step in this optimizing process.

$\varepsilon_{e,eff}$, Z and α can be calculated from the Scattering matrix(S_{11} S_{12} S_{21} S_{22}), which is measured using the network analyzer, according to the following equations:

$$
\begin{aligned}
Z_{in} &= Z \cdot \frac{(Z_0 + Z) + (Z_0 - Z)e^{-2(\alpha + i\beta)l}}{(Z_0 + Z) - (Z_0 - Z)e^{-2(\alpha + i\beta)l}} \\
S_{11} &= \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \\
S_{12} &= \frac{4Z_0 Z_{in}}{\left[(Z_0 + Z)e^{(\alpha+i\beta)l} + (Z_0 - Z)e^{-(\alpha+i\beta)l}\right](Z_{in} + Z)} \\
\left(\frac{2\pi f}{c\beta}\right)^2 &= \varepsilon_{e,eff}
\end{aligned}
\qquad (2)
$$

where $Z_0 = 50\Omega$ is the impedance of the network analyzer, β is the propagation constant of the electrical channel, l is the length of the electrode, c is vacuum light speed, and f is frequency. These equations are valid under the assumption that the electrode subjected to test is a uniform transmission line. Since S_{11} and S_{12} are complex numbers, there are five equations from which $\varepsilon_{e,eff}$, Z and α can be calculated.

(2) In testing the device

The output power setting function and the frequency sweep mode setting function of the network analyzer system make it a convenient power source in the device-testing process. It can provide a continuously-frequency-tunable source with frequency up to 50GHz and with four frequency-sweep modes (ramp, step, single point, and frequency list) [1]. These properties offer significant convenience for device testing.

(3) In device packaging

In the last phase of this research, the modulator will be packaged. Two connectors will be added to the two ends of the electrode to provide two coaxial ports, and a stand is being designed to support the whole device. These connectors and the stand may affect the performance of the modulator. The network analyzer enables us to evaluate this influence. This information provided by the network system will help us optimize the stand structure.

4. Equipping with accessories[8]

Fig. 3 is a picture of a fabricated modulator. The yellow portions on the top are top electrodes made from gold under which there are two optical channels, two layers of cladding materials, and a bottom electrode. The whole device is fabricated on a silicon wafer.

We can see that the top electrodes have a coplanar waveguide (CPW) structure. Since the original network analyzer system listed in the abstract can measure only coaxial devices, we needed to equip it with some accessories to make the network analyzer system feasible for testing non-coaxial devices. We chose the Wiltron 3680 series Universal Test Fixture (UFT) (shown in Fig. 4) to accomplish this task. The Wiltron 3680 series UFT includes:

(1) Model 3680V Universal Test Fixture (UTF): It supports on-substrate testing of micro strip and coplanar waveguide (CPW) devices. The critical components of the UTF are two V connectors that are mounted on a fixed connector block and a movable connector block respectively. The test device is clamped directly into the launchers of the fixture. By moving the movable connector block, UTF can accommodate a variety of sizes and configurations of test devices.
(2) Model 36801 Right-Angle Launcher: The Right Angle Launcher (RAL) is used to make multi-port connections as well as right-angle connections to the test device.
(3) Model 36803 Bias Probe: The bias probe is used either as a bias probe or as a hold-down for components. When it serves as a hold-down, a dielectric probe is used.
(4) Model 36802 MMIC Attachment: The MMIC attachment is used to support testing of small devices and substrates where it is not feasible to make connections with the UTF jaw.
(5) Model 3680B-15M & Model 3680-25C Calibration/Verification Kits: These kits contain precision substrates with precisely-known impedance for calibration. These kits also contain verification substrate for use in confirming the calibration accuracy. The difference between these two kits is that 3680-15M is for the micro strip device and 3680-25C is for the CPW device.

Equipped with a Wiltron 3680 series Universal Test Fixture, the network analyzer system can measure both coaxial and non-coaxial (CPW and micro strip) devices with frequencies up to 50 GHz. The network analyzer system equipped with Wiltron 3680 series Universal Test Fixture is shown in Fig 5.

Section 5, Measurement using the network analyzer system

(1) Electrode Measurement:

Fig. 6 shows the arrangement for electrode measurement. Fig. 6(a) shows the entire setup; Fig.6 (b) shows the test fixture portion. In this setup, two Right-Angle-Launchers are mounted on the test fixture, and are connected to the two ports of the network analyzer respectively. The substrate with an electrode on it is clamped into the two Right-Angle-Launchers. In this way, the microwave coming out from one port can travel through the electrodes and go back through the other port. By properly setting the frequency-sweep mode, we can measure the scattering matrix of the electrode at a wide frequency range. This measurement can be substituted in equation 2 to get the effective dielectric constant, impedance, and attenuation constants.

(2) Device Test

Fig. 8 shows the setup for device-test in which one of the electrode ports is terminated by a $50\,\Omega$ terminator through a Right-Angle-Launcher and the other electrode port is connected to the network analyzer through another Right-Angle-Launcher. The two microscope objectives and the under test modulator form an optical channel. The light from a laser enters through the left microscope objective, then travels through the modulator and goes out through the right microscope objective. The output light intensity is measured by a detector and is compared with the input modulation signal generated by the network analyzer to evaluate the modulation efficiency.

(3) Device Package

The network analyzer will be used in the modulator packaging process in the near future.

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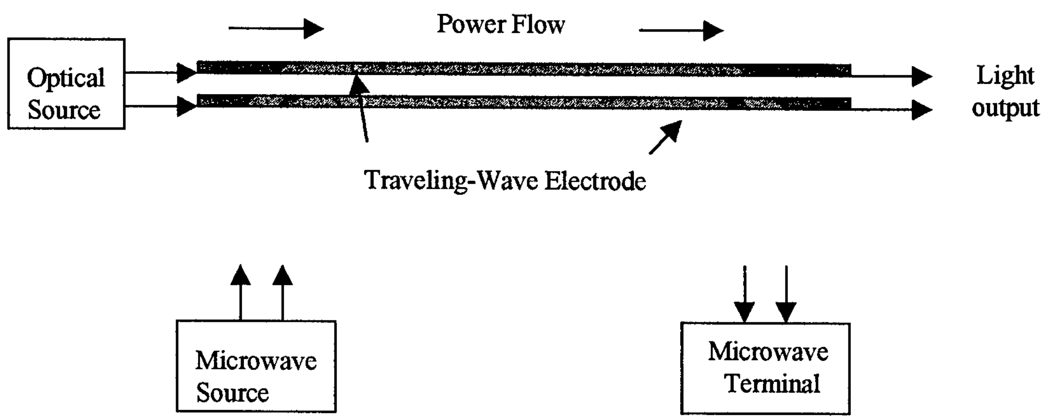
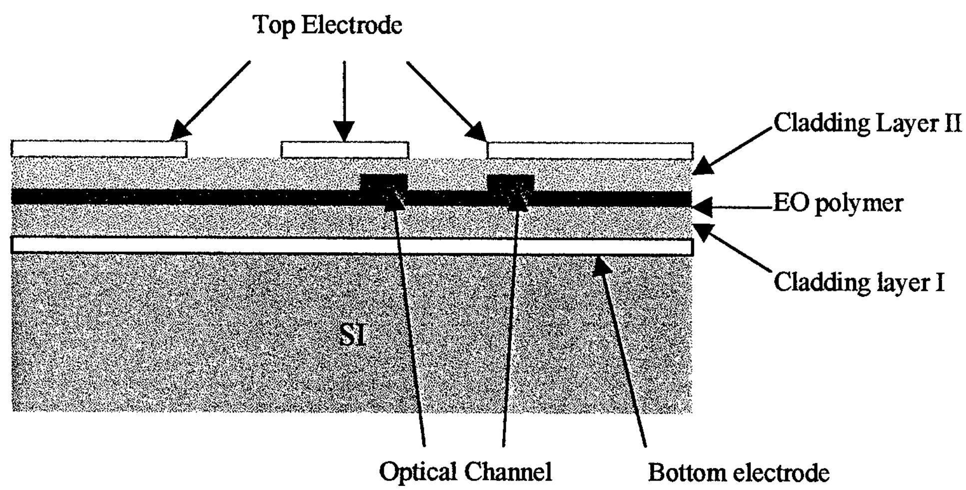


(a) General Structure



(b) Cross section structure

Fig. 1 High-speed Directional coupler modulator based on EO polymer

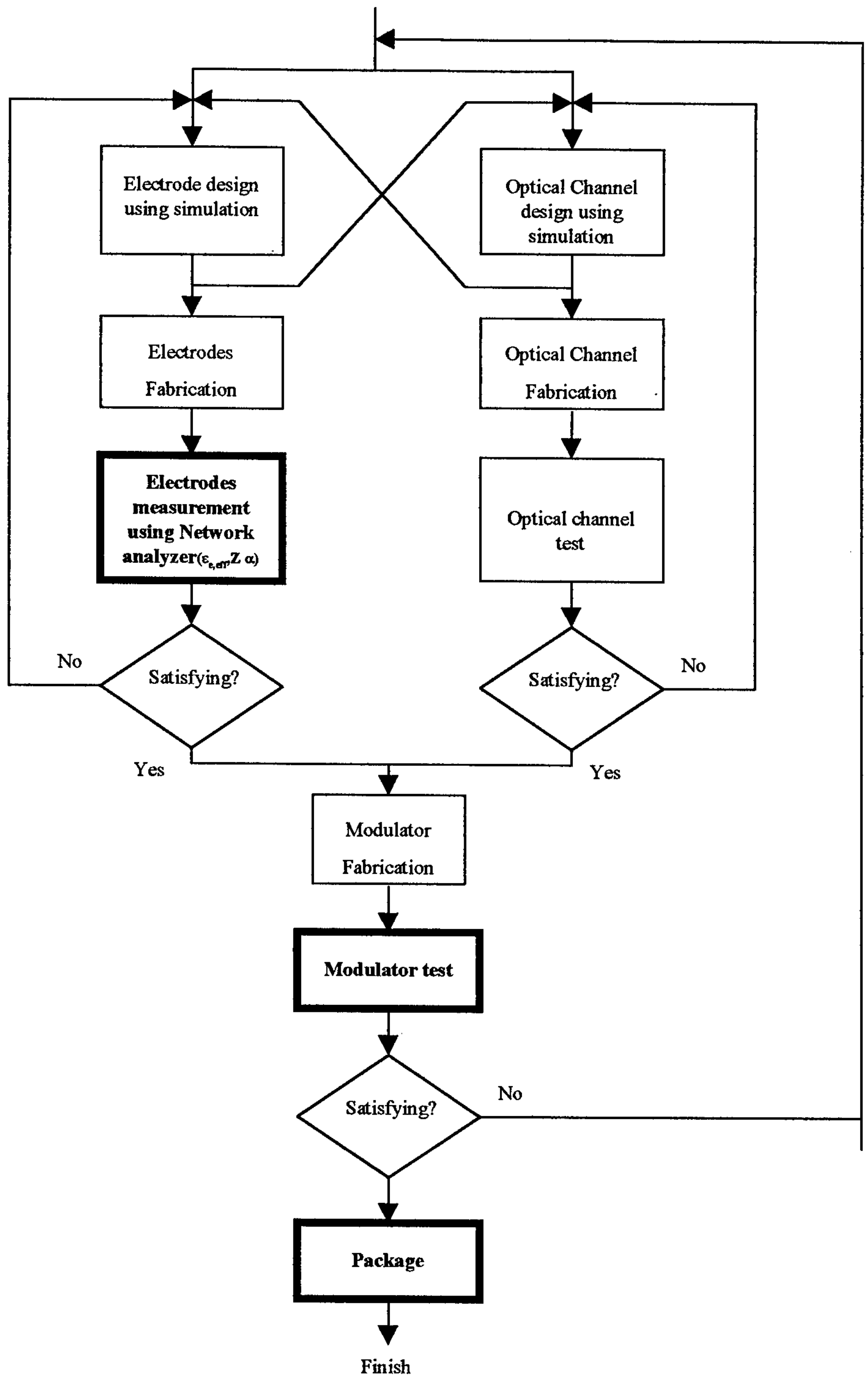


Fig. 2 High-speed EO polymer based Modulator design process
(the steps in which network analyzer is used are bolded)

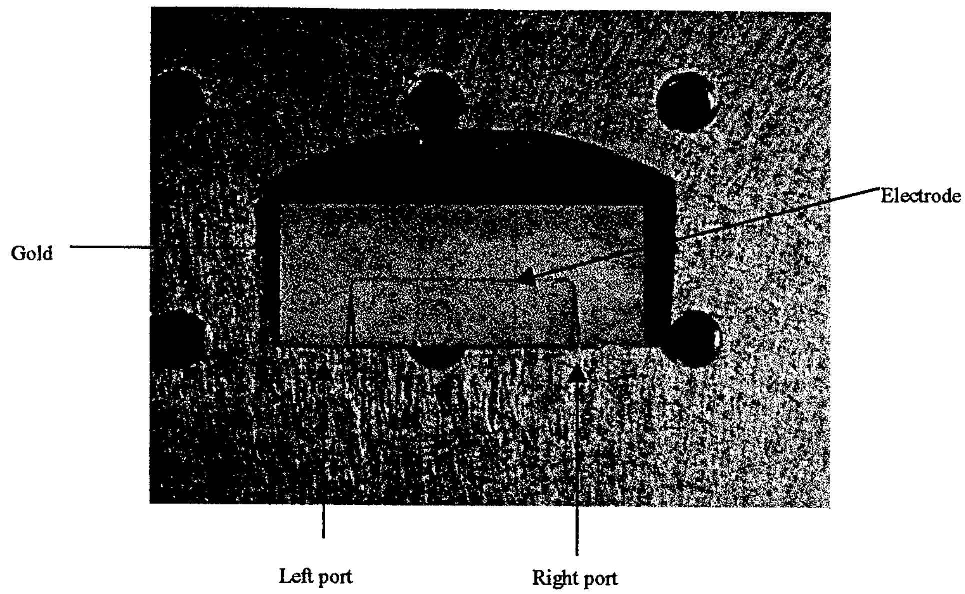
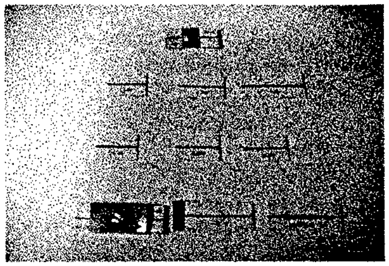
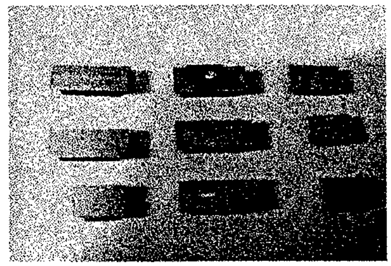


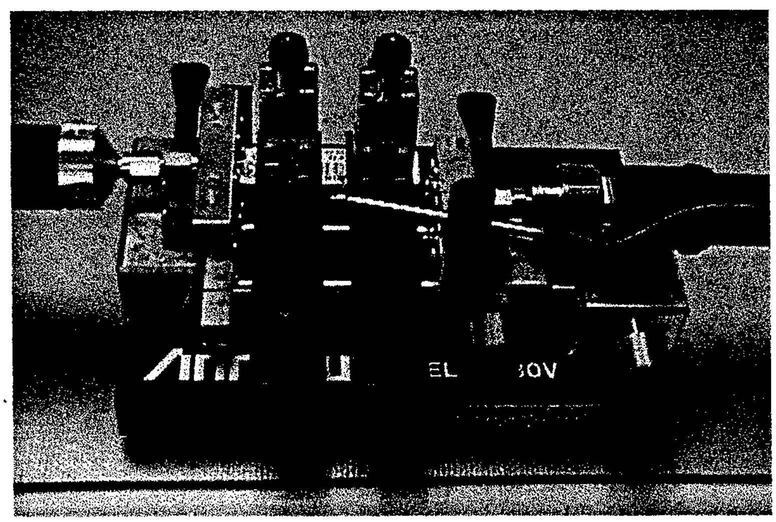
Fig. 3 Electrode Structure





(a) (b)

(c)



(d)

Fig. 4 Wiltron 3680V series Universal Test Fixture (UTF)

(a) Wiltron 3680B-15M calibration/verification Kit One

(b) Wiltron 3680-25C calibration/verification Kit

(c) W iltron 36802 MMIC Attachment

(d) Wiltron 3680V series Universal Test Fixture (UTF)

& Wiltron 36801 Right-Angle Launchers

& Wiltron 36803 Bias Probes

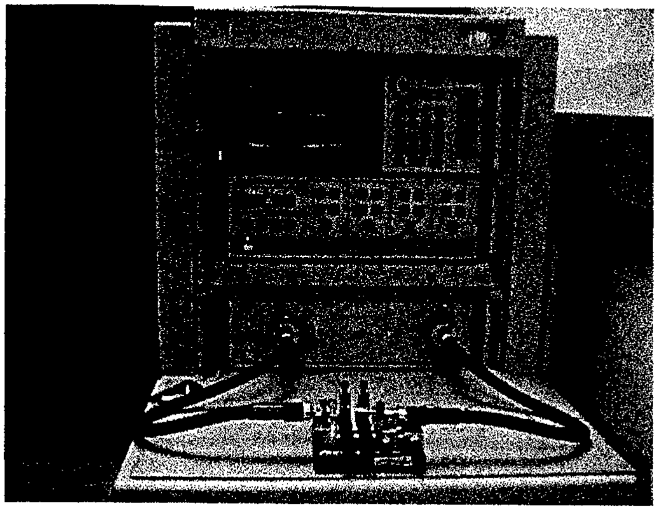
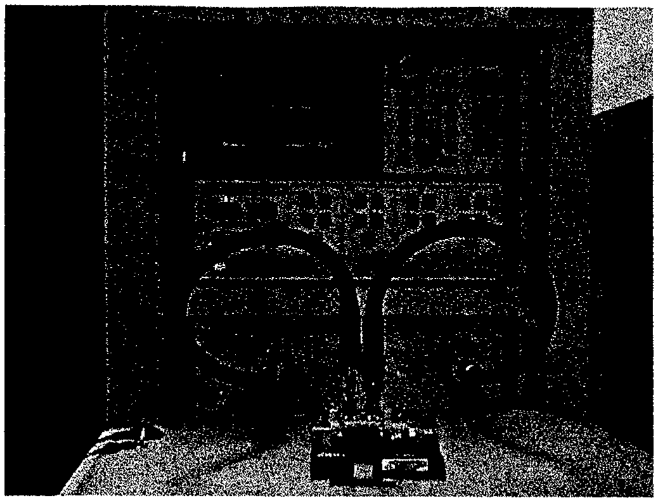


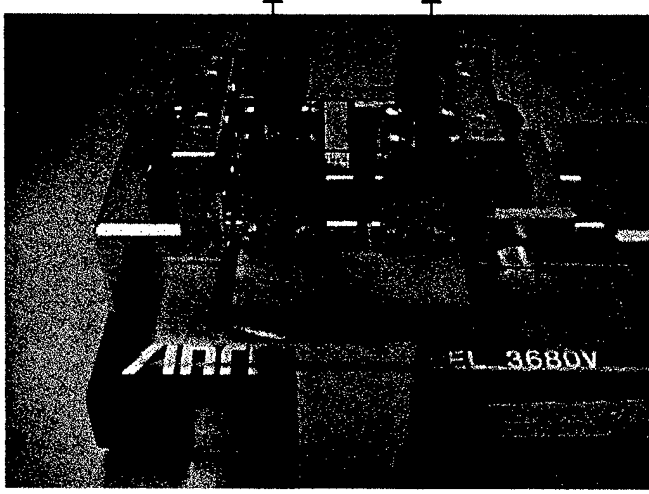
Fig.5 HP 8510C network Analyzer Equipped with Wiltron 3680V series Universal Test Fixture (UTF)



(a) Whole Setup

To Network Analyzer

Port 1 port 2



Device under test

(b)Test Fixture Portion

Fig. 6 Electrodes Measurement setup

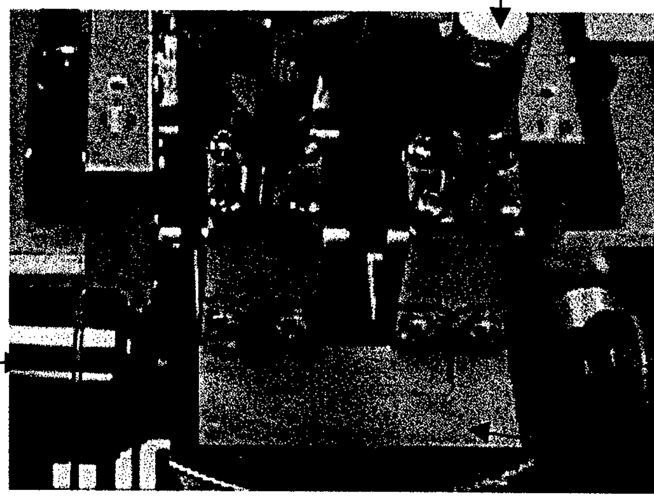


Fig. 7 Setup for modulator test